

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

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#14/APPEAL  
Brief

In re Patent Application of

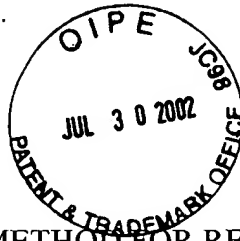
Richard L. Sutherland, et al.

Art Unit: 1756

Serial No. 09/577,166

Examiner: ANGEBRANNDT, M.

Filed: May 24, 2000



For: A SYSTEM AND METHOD FOR REPLICATING VOLUME  
HOLOGRAMS

Box: Appeal  
Assistant Commissioner of Patents  
Washington, D.C. 20231

**APPEAL BRIEF**

This is an Appeal Brief under 37 C.F.R. § 1.192 in connection with the decision of the Examiner mailed on December 31, 2001. A Notice of Appeal was filed on April 30, 2002. Each of the topics required by Rule 192 is presented herewith and is labeled appropriately.

**(1) Real Party In Interest**

The real party in interest is Science Applications International Corporation having an office at 10260 Campus Point Drive, San Diego, California 92121.

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**(2) Related Appeals And Interferences**

There are no other appeals or interferences related to this case.

**(3) Status Of Claims**

Claims 1-48 are pending.

Claims 1-43, 46 and 48 have been rejected.

Claims 44 and 45 are under objection.

Claim 47 is allowed.

Appeal is taken with claims 1-46 and 48.

**(4) Status of Amendments**

There are no amendments after final rejection.

**(5) Summary Of The Invention**

The invention is an improved method and system for contact printing at least one master hologram. More particularly in at least one embodiment of the present invention, the at least one master hologram has a variable diffraction efficiency. (See pg. 22, lines 20-25, Figure No. 6, #35). The variable diffraction efficiency of the master hologram is reproducible via contact printing as a result of, *inter alia*, the material and grating characteristics of the master hologram. (See pg. 11, line 30 through pg. 12, line 15). The contact printing method and system of the present invention replicates the master hologram, including the variable diffraction efficiency characteristics thereof, in at least one holographic blank, forming at least one replica hologram. (See pg. 22, lines 15-20). The at least one master hologram having a variable diffraction efficiency is reproducible through contact printing irrespective of whether the master hologram is a transmission or reflection hologram. (See pg. 4,

lines 23-25; Figure Nos. 3 and 4). Further, two or more switchable master holograms in stacked formation may be used in contact printing with two or more holographic blanks in order to form replicas thereof. (See pg. 26, ll. 16-18; Figure 11(a)). The replication through contact printing is accomplished using the switching capabilities of the at least two master holograms. (See pg. 26, ll. 16-23; Figure 11(a)). This is merely meant to be a summary of the invention and is in no way intended to limit the pending claims.

**(6) Issues**

- A. Whether the Examiner's rejection of claims 1, 2, 9-11, 22-24, 32-43 and 46 under 35 U.S.C. 103(a) as being unpatentable over Sturdevant '946, in view of Redfield '861, Hall et al. '326, Amako et al. '214 and Sutherland et al. "Bragg Gratings in an acrylate..." is proper.
- B. Whether the Examiner's rejection of claims 32-35 and 37-40 and 46 under 35 U.S.C. 103(a) as being unpatentable over Sturdevant '946, in view of Redfield '861, Hall et al. '326 and Amako et al. '214 is proper.
- C. Whether the Examiner's rejection of claims 1-31 under 35 U.S.C. 103(a) as being unpatentable over Sutherland et al. WO 98/04650, in view of Margerum et al. '568 combined with either Eguchi et al. JP 03-188479, Wreede et al. '118 or Ikeda et al. EP 0087281 and further in view of Hall et al. '326 and Amako et al. '214 is proper.

D. Whether the Examiner's rejection of claim 48 under 35 U.S.C. 103(a) as being unpatentable over Gambogi et al. '011, in view of Hall et al. '326, Kato et al. '504, Sutherland et al. WO 98/04650 and Ikeda et al. EP 0087281 is proper.

**(7) Grouping of Claims**

Claims 1-48 are arranged into the groups listed below. Claims within a group stand and fall together. Groups of claims, however, do not stand or fall together with other groups of claims.

GROUP	CLAIMS
I	1-11, 22-31
II	12-21
III	32-43, 46
IV	48

**(8) Argument**

**A. The Examiner's Rejection of Claims 1, 2, 9-11, 22-24, 32-43 and 46 under 35 U.S.C. 103(a) as being Unpatentable over Sturdevant '946, in View of Redfield '861, Hall et al. '326, Amako et al. '214 and Sutherland et al. "Bragg Gratings in an acrylate..." is Improper.**

*1. The Cited References Do Not Teach the Use of a Variable Diffraction Efficiency Master Hologram in Optical Contact Printing Methods and Systems, Wherein the Resulting Replica Also Has the Attribute of Variable Diffraction Efficiency as is Proposed by Each of the Claims*

Each of the independent claims 1, 22, 32, and 46 of Groups I and II refer to at least one variable diffraction efficiency hologram which is to be used in contact printing. The variable diffraction efficiency hologram that is duplicated is referred to

for discussion purposes below as the master hologram. The claims of Group I and II recite that the diffraction efficiency of the master hologram be variable as opposed to static. Contrary to the Examiner's assertion, none of the references cited by the Examiner teach or suggest use of a method or system for using a master hologram through contact printing, wherein the master hologram has a variable diffraction efficiency as shown in insert A of Appendix A. As confirmed by the Examiner, the term "variable diffraction efficiency" describes a hologram which can assume varied diffraction efficiencies **after recording**. (Final Office Action ¶ 1)(emphasis added). The phrase "variable diffraction efficiency" as defined in the specification refers to multiple states of diffraction efficiency. (Specification at pg. 25, lines 1-11).

The Group I claims further recite use of a variable diffraction efficiency master hologram in optical contact printing methods and systems, wherein the resulting replica also has the attribute of variable diffraction efficiency as shown in insert B of Appendix A. Hence the use of the word "replica." Said another way, the invention of Group I describes contact printing of a hologram having variable diffraction efficiency such that the contact printed replica also exhibits variable diffraction efficiency. The ability to replicate variable diffraction efficiency holograms through contact printing is not taught or suggested by the cited art, either singularly or in combination.

The Examiner argues that Hall et al. (United States Patent No. 5,471,326)("Hall"),

teaches the use of computer generated holograms for copying processes and Amako et al. '214 teaches means for their generation as well as the advantages that a number of different holograms can

be replayed without moving the master or the need to generate a (sic) optically produced master. These are clear advantages to the use of computer generated holograms in LC materials as the masters.

(Final Office Action, pgs. 3-4). More particularly, the Examiner directs the undersigned representative to Column 10, lines 48-50 of (“Hall”) for the proposition that optically or computer generated holograms are used for contact copying. (Final Office Action, pg. 3). Initially, the undersigned representative points out that Hall is directed to beam steering through the use of beam diffraction using a holographic optical element (HOE). Hall is not directed to the formation or replication of holograms. Further, the holograms comprising the HOE are static holograms. Consequently, the discussion in Hall regarding hologram formation is with respect to the formation of static holograms. Referring to Hall, Column 10, lines 47-50 states,

- i. “[a] master hologram [“MH”] for each hologram [“H”] employed can be either a computer generated hologram or an optically generated hologram.”
- ii. “Any additional holograms [H] can be copied by contact printing.”

These are two separate sentences, stating two separate steps. Referring to insert C of Appendix A, step (i) states that the static hologram [H] may be generated by a master hologram [MH] which is computer or optically generated. Step (ii) separately states that the static hologram [H] formed by step (i) may be copied using contact printing.

While the static hologram is initially recorded using a computer generated master, the method of recordation is not through contact printing. The use of contact printing is limited to duplication of the static hologram in order to mass produce other static holograms. The use of a static master hologram in contact printing to produce static replicas of the static master hologram is known. Further, the static hologram(s) generated from the master hologram are only replicas of the master hologram at a fixed diffraction efficiency. Consequently, though Hall may “teach or suggest the use of computer generated holograms in copying processes,” Hall does not teach the use of a master hologram having a variable diffraction efficiency in a contact copying process as required by claims 1, 22, 32, and 46. Further, Hall does not teach or suggest the replication of a master hologram having a variable diffraction efficiency, wherein the replica also exhibits variable diffraction efficiency as described by at least claims 1 and 22.

The Examiner points to United States Patent No. 5,682,214 (“Amako”) to show the generation of computer generated holograms using liquid crystal devices. Amako describes the use of an electrically controllable liquid crystal CGH in order to control input beams that are used in image formation. There is no teaching or suggestion in Amako of hologram replication by contact copying. The claims of the pending application propose the use of a variable diffraction efficiency master hologram in contact printing. While the CGH described in Amako may exhibit variable diffraction efficiency under computer control, Amako does not teach or suggest the replication of this CGH by contact printing or by any other method or means. At most, Amako describes the process illustrated in insert D of Appendix A,

wherein a hologram that may, under computer control, exhibit varied diffraction efficiency, is used to form a non-holographic image. The non-holographic image does not and cannot exhibit the holographic properties of the hologram. Amako does not teach or suggest the limitations of the pending claims.

While the cited art teaches and suggests using a single master computer generated hologram to generate multiple static holograms through non-contact printing, the prior art does not teach the use of a single master computer generated hologram in a contact printing process. Further, in the non-contact processes where the computer generated hologram is used as the master hologram, the resulting holograms made during this process are not replicas of the variable diffraction efficiency computer generated hologram as the resulting holograms do not exhibit the variable diffraction efficiency characteristics of the computer generated hologram. These deficiencies are not cured by Sturdevant, Redfield, or Sutherland. Sturdevant is cited by the Examiner as teaching

“a continuous process where the holographic recording medium is preexposed without any pattern using UV light (21), Then the hologram is exposed using a laser and contact exposure through a holographic master (85) and then post exposed using a UV lamp (91).”

The Examiner cites Redfield as teaching a precure for depleting oxygen and reducing the induction period; carrying out the fixation exposure using a reference beam; and the use of spatial light modulators. While Sutherland is cited for teaching pre-exposure to reduce the induction period; post exposure fixation/postcuring; and the ability to switch an LC hologram on and off in response to a potential applied across electrodes. None of these references teach or suggest (a) a variable diffraction

efficiency master hologram used in contact printing and (b) contact printing of a master hologram having a variable diffraction efficiency resulting in a replica hologram having the variable diffraction efficiency characteristics of the master hologram, at least one of which is required in each of the independent claims.

Pursuant to the requirements for establishing a *prima facie* case of obviousness, all the claim limitations must be taught or suggested by the prior art. *In re Royka*, 490 F.2d 981, 180 USPQ 580 (CCPA 1974). Referring to MPEP Section 2142,

[t]o establish a *prima facie* case of obviousness, three basic criteria must be met. First, there must be some suggestion or motivation, either in the references themselves or in the knowledge generally available to one of ordinary skill in the art, to modify the reference or to combine reference teachings. Second, there must be a reasonable expectation of success. Finally, **the prior art reference (or references when combined) must teach or suggest all the claim limitations.** The teaching or suggestion to make the claimed combination and the reasonable expectation of success must both be found in the prior art, and not based on the applicant's disclosure. *In re Vaeck*, 947 F.2d 488, 20 USPQ2d 1438 (Fed. Cir. 1991).

(emphasis added). As discussed herein, the Examiner has failed to address at least the claim limitations of (a) a variable diffraction efficiency master hologram used in contact printing and (b) contact printing of a master hologram having a variable diffraction efficiency resulting in a replica hologram having the variable diffraction efficiency characteristics of the master hologram. The Examiner has not met the initial burden of factually supporting a *prima facie* conclusion of obviousness and the undersigned representative is under no obligation to submit evidence of nonobviousness. MPEP § 2142. Consequently, the undersigned representative

respectfully requests allowance of the claims as no rebuttable *prima facie* case of unpatentability has been established.

2. Assuming that the Cited References Do Suggest the Discrete Limitations of the Claims, There is No Reasonable Expectation that the Combination of These Limitations Would Result in the Claimed Subject Matter

Assuming, *arguendo*, that each of Hall and Amako stood for the propositions set forth by the Examiner above, as evidence by the attached declaration of Dr. Richard Sutherland and the arguments and evidence presented herein, there is no reasonable expectation that the combination of these propositions would successfully result in the claimed subject matter. *See In re Rinehart*, 531 F.2d 1048, 189 USPQ 143 (CCPA 1976). Since at least some degree of predictability is required in order to sustain an obviousness rejection and the evidence shows no reasonable expectation of success, the Examiner has not established a *prima facie* case of unpatentability. *See* MPEP § 2143.02. More particularly, the computer generated hologram in a liquid crystal device described in Amako cannot be used as a master hologram with variable diffraction efficiency in a contact printing scheme because: (a) the holograms of Amako et al. (CGH in LCD) have a limited pitch dictated by fundamental laws of electromagnetism; (b) the limited pitch of the holograms of Amako et al. make them unsuitable as masters for contact copying due to fundamental properties of diffraction; (c) the physical constraints, e.g., limited pitch, on the holograms of Amako et al. make it impossible to form reflection holograms that could be used as masters in hologram replication as set forth in the claims.

(a) The Holograms of Amako et al. Have Limited Pitch

Amako et al. physically generate their holograms by applying an electric field to a liquid crystal (a dielectric) confined between two electrodes. Such a structure is known as a capacitor and is illustrated in Fig. 1 of Appendix B. The electrodes have an area  $L \times W$  ( $W$  is the dimension perpendicular to the paper in Fig. 1) and a separation  $d$ . Normally, the separation  $d$  is much smaller than the lateral dimensions of the electrodes ( $d \ll L$ ,  $d \ll W$ ) [D. R. Corson and P. Lorrain, *Introduction to Electromagnetic Fields and Waves*, W. H. Freeman and Co., San Francisco, 1962, Ch. 2]. This makes the device useful since under these conditions the field between the electrodes is uniform. However, the laws of electromagnetism require that the electric field not drop abruptly to zero at the edge of the electrodes [D. Haliday and R. Resnick, *Physics for Students of Science and Engineering*, John Wiley & Sons, New York, Second Edition, 1962, Ch. 30]. There are thus fringing field lines near the edges, as shown in Fig. 1 [D. R. Corson and P. Lorrain, *Introduction to Electromagnetic Fields and Waves*, W. H. Freeman and Co., San Francisco, 1962, Ch. 3], and the electric field falls gradually to zero outside the capacitor. The field has appreciable strength for a distance  $\sim d$  from the edge of the electrodes. Since  $d \ll L$  and  $d \ll W$ , this fringe field can normally be ignored in a large number of applications.

However, consider the case when capacitors are placed in an array as shown in Fig. 2 of Appendix B. To avoid fringe fields from influencing adjacent capacitors, the capacitors must be separated by a distance  $\sim 2d$ . This is schematically the type of

array used for switching pixels in LCDs. Actually, in LCDs there is a single common ground plane as illustrated in Fig. 3 of Appendix B [P. Yeh and C. Gu, *Optics of Liquid Crystal Displays*, John Wiley & Sons, New York, 1999, Ch. 6; see also the classic chapter by F. C. Luo, “Active matrix LC displays,” in *Liquid Crystals—Applications and Uses*, World Scientific, 1993, Ch. 15]. The principle is the same, however, and the pixel electrodes must be separated by a distance  $\sim 2d$  to avoid cross talk between pixels. This is an issue for all LCDs [P. Yeh and C. Gu, *Optics of Liquid Crystal Displays*, John Wiley & Sons, New York, 1999, Ch. 6]. Note that this type of pixel electrode arrangement is similar in concept to those given in Amako et al. (see Figs. 3(b), 8, and 13 of Amako et al.).

Of importance here is the physical concept that the lateral dimensions of the pixel electrodes must be large compared to the thickness of the LC layer (i.e.,  $d$ ). Figure 4 of Appendix B illustrates what would happen if this were not the case. The fringe field lines totally overlap the area between adjacent electrodes. The resultant cross talk would totally obliterate the desired field pattern. For example, if every other electrode were turned off to create a periodic modulation pattern, the dielectric between the unactivated electrodes would sense a field of nearly the same magnitude as that between activated electrodes, and the desired periodic modulation would be washed out.

Most LCDs have a thickness of 4-10  $\mu\text{m}$  [P. Yeh and C. Gu, *Optics of Liquid Crystal Displays*, John Wiley & Sons, New York, 1999, Ch. 6]. Using 5  $\mu\text{m}$  as a representative example, in order to meet the condition given above, the electrode

dimensions should be  $\sim 50\text{ }\mu\text{m}$ . This is approximately the pixel size ( $40\times 45\text{ }\mu\text{m}$ ) quoted by Amako et al. (column 9, lines 12-19). The visible portion of a pixel is often reduced somewhat due to storage capacitor, TFT switch, etc. taking up additional real estate on each pixel [P. Yeh and C. Gu, *Optics of Liquid Crystal Displays*, John Wiley & Sons, New York, 1999, Ch. 6]. Each electrode must be thus separated by a distance  $\sim 10\text{ }\mu\text{m}$ . The minimum pitch (defined by adjacent pixels ON and OFF) is thus  $\sim 100\text{ }\mu\text{m}$ . The types of holograms made optically in PDLCs as is the case with the current invention, have pitch  $< 1\text{ }\mu\text{m}$ . To obtain this dimension in the LCD would require a  $100\times$  reduction in electrode dimensions and a concomitant reduction in LC layer thickness. Using the above example, this would be  $d \sim 0.05\text{ }\mu\text{m}$ , i.e., less than an optical wavelength. Aside from the technological difficulties associated with making an LCD this thin, the maximum phase modulation that could be achieved is  $1/100^{\text{th}}$  that achieved in a  $5\text{-}\mu\text{m}$  thick device. Since the diffraction efficiency scales as the square of this factor, it would be smaller by a factor of 10,000. Noting that pitch  $< 0.2\text{ }\mu\text{m}$  is often desired, the problem is compounded.

Hence, the holograms of Amako et al. have limited pitch dictated by the basic laws of physics. Amako et al. gives no teaching for overcoming this limitation. In fact, all of the applications of Amako et al. make use of holograms with this coarse pitch.

Contrasting the holograms of Amako et al., i.e., CGH in LCD, with electrically switchable holograms in PDLCs shown in Figs. 5 and 6 of Appendix B, Amako et al. create a hologram, i.e., fringe pattern, by alternately turning adjacent pixels ON and

OFF. (Note that this is the basic scheme. Amako also gives examples where multiple pixels, e.g., 9, make up the basic holographic unit, as opposed to the 2 shown here. However, using more than 2 only exacerbates the problem by enlarging the pitch. The significance of the pitch is made clear in section (b) below.) Where a field is applied, LC molecules rotate as shown in Fig. 5. This alternating patterning of LC molecules creates the fringe pattern that is a hologram. Amako et al. thus electrically generate each fringe of the hologram individually. This technique limits the pitch  $\Lambda$  according to the laws of electromagnetism, to a size discussed above. Conversely, in the optically generated hologram in a PDLC, the pitch can actually be smaller than the optical wavelength that generates it. However, it is not limited to this size and can be larger than a wavelength as well. Each fringe consists of alternating LC droplet and polymer layers. An electric field is applied uniformly to the whole hologram. This modulates the diffraction efficiency of the hologram, and can turn it completely off at a sufficiently high voltage. Thus, although both types of hologram are electrically controlled, the similarity is only superficial. The holograms are fundamentally different, primarily in their diffraction properties related to their achievable pitch, as is described further in section (b).

(b) The Holograms of Amako et al. Are Unsuitable for Contact Copying

Figure 7 of Appendix B illustrates the creation of a master hologram by both optical holography and computer generated holography in an LCD. In optical holography, two coherent light beams, a reference beam and an object beam, interfere

in the holographic medium and generate the light intensity pattern shown. Through the response of the medium (e.g., photopolymerization), an index modulation pattern is imprinted. The CGH in LCD creates this index modulation through activation of alternating electrodes, with the response of the LC molecules to the electric field pattern providing the modulation. In order to optically generate a hologram with the same pitch as the CGH in LCD, the angle between the two beams should be small. For example, to create 100- $\mu\text{m}$  fringes using 532 nm (green) light, the angle between the two beams would be  $0.2^\circ$ , assuming a refractive index of 1.5. This master is now used to attempt contact printing of a replica, with a single incident reference beam, as illustrated in Fig. 8 of Appendix B. A “replica” is defined by Random House Dictionary as “any close or exact copy or reproduction, *esp. on a smaller scale.*” In order to produce a replica of the master according to this definition, the reference wave and diffracted wave must superpose to create a close or exact copy of the intensity pattern shown in Fig. 7 within the blank material. The question of the intensity pattern within the blank material is answered by diffraction theory, a well understood and experimentally validated branch of optics in existence for over 100 years.

As established in the previously submitted Declaration of Mr. Richard Sutherland, PhD, the diffraction pattern produced by a hologram of the type generated by Amako et al. is in the so-called Raman-Nath regime. This type of grating was originally treated by Raman and Nath [C. V. Raman and N. S. N. Nath, *Proc. Ind. Acad. Sci.* A2, 413-420 (1935)] and since by numerous authors [see e.g., W. R. Klein

and B. D. Cook, *IEEE Trans.* **SU-14**, 123-134 (1965)], and has been experimentally validated in a variety of media [F. H. Sanders, *Canad. J. Phys.* **14**, 158-171 (1936); S. Parthasarathy, *Proc. Ind. Acad. Sci.* **A3**, 442 (1936); O. Nomoto, *Proc. Phys. Math. Soc. Jap.* **24**, 380-400 (1942); W. G. Mayer, *J. Ac. Soc. Am.* **36**, 779-781 (1964); W. R. Klein et al., *J. Ac. Soc. Am.* **38**, 229-233 (1965)]. The principal result of directing a beam of light onto such a grating is that the light exits the medium with a periodic phase modulation across its wave front. The light exiting the hologram has no amplitude modulation, only phase modulation. This is what Amako et al. shows in Fig. 6 (phase shift) and Fig. 7 (no amplitude modulation) of the '214 patent for an electrically induced birefringence mode of the LCD. A periodic phase modulation is *equivalent* mathematically to the superposition of an infinite number of modes consisting of plane waves propagating at an angle of  $\tan^{-1}(\lambda/\Lambda)$  with respect to one another, where  $\lambda$  is the wavelength of the incident light. Importantly, all of these modes are present simultaneously in the exit beam, and in fact *must* be present in order to produce the phase-modulated beam by superposition. With the application of diffraction theory, it follows that as this intensity pattern propagates into the replicating medium, it cannot reproduce the required intensity distribution given in Fig. 7 of Appendix B.

The geometry of the situation is illustrated in Fig. 9 of Appendix B. This is an example of a square master hologram of dimension  $a$ , although the same general results will be expected using a rectangular or circular hologram. The incident reference beam exits the hologram with a phase modulation. This light diffracts as it

propagates along the  $z$  axis. For simplicity, the example concentrates on the intensity variation along the  $x$  axis (i.e., for  $y=0$ ). By symmetry, the variation along the  $y$  axis will be the same. The form of the diffracted light is found by substituting the hologram output wave into the diffraction integral. This is a standard procedure that has been established theoretically and experimentally for over 100 years and is treated in numerous text books [M. Born and E. Wolf, *Principles of Optics*, Fifth Edition, Pergamon Press, New York, 1975, Ch. 8; F. A. Jenkins and H. E. White, *Fundamentals of Optics*, Fourth Edition, McGraw-Hill Co., New York, 1976, Ch. 18; J. D. Gaskill, *Linear Systems, Fourier Transforms, and Optics*, John Wiley & Sons, New York, 1978, Ch.10; J. W. Goodman, *Introduction to Fourier Optics*, McGraw-Hill Co., New York, 1968, Ch. 4].

Further to the example, the case is presented for zero modulation. This is the same as an empty aperture or a CGH in LCD with zero voltage applied to each pixel. The size of the aperture is  $a=1$  cm, and the wavelength is  $\lambda=0.5$   $\mu\text{m}$  (green light). The series of plots in Fig. 10 of Appendix B show how the intensity evolves as the beam propagates along the  $z$  axis. In some of the plots the vertical dashed line marks the hard boundaries of the aperture. Clearly, the light pattern is not uniform even though the light incident on the aperture has uniform intensity. When the light has propagated a distance of  $10^5$  cm, the intensity assumes the familiar Fraunhofer pattern quoted in many texts [see, e.g., M. Born and E. Wolf, *Principles of Optics*, Fifth Edition, Pergamon Press, New York, 1975, Ch. 8; J. W. Goodman, *Introduction to*

*Fourier Optics*, McGraw-Hill Co., New York, 1968, Ch. 4]. This validates the calculation of the diffraction integral.

Next we consider a hologram in the aperture with  $\Lambda=100\text{ }\mu\text{m}$  and a phase modulation of  $\pi$  radians. This is typical of a CGH in LCD (see Fig. 6 of Amako et al.). The evolution of the intensity pattern is shown in Fig. 11 of Appendix B. In this case there is considerable intensity modulation in the near field ( $z=0.1\text{-}1.0\text{ cm}$ ). At large distances from the hologram, this evolves into the familiar Fraunhofer diffraction pattern for a phase grating (cf. Fig. 4-8 of Goodman where the phase modulation is 4 instead of  $\pi=3.14\dots$  used here). For the plot with  $z=10^4\text{ cm}$ , the various diffraction modes are easily resolved and numbered. The last plot zooms in on the 0-order. Comparing the shapes to the corresponding plot in Fig. 10, i.e., each mode carries the imprint of the empty aperture. Further, at least 9 modes are visible, but they are only resolved at great distances from the hologram. In the near field of contact printing all of the modes are superposed to create the modulation seen in the first two plots in Fig. 11. For the sake of clarity, the holograms of Amako et al. are in the far field, not the near field of contact printing. The far field can be accessed by passing the diffracted light through a converging lens [M. Born and E. Wolf, *Principles of Optics*, Fifth Edition, Pergamon Press, New York, 1975, Ch. 8]. It is very evident that Amako et al. do this as seen in Fig. 1 of Amako et al.

The plots in Fig. 12 of Appendix B zoom in to show the detail in the near field. The solid curves in these plots are the intensity patterns of diffracted light at various positions along the  $z$  axis. They are compared to the dashed curves, which

show the light intensity pattern that is necessary to replicate the master hologram (see Fig. 7 of Appendix B). Clearly, the light pattern is not an exact or even close copy of the desired pattern. This is a result of the simultaneous presence of all diffracted modes. The higher order modes are undesirable as they are present as ghost images in thin holograms [L. Solymar and D. J. Cooke, *Volume Holography and Volume Gratings*, Academic Press, New York, 1981, Ch. 5]. This is an unacceptable condition for mass production of high fidelity holograms by contact printing. The distances chosen here are representative of what would be used in contact printing. The proximity of the holograms can be no closer than the thickness of the cover glass in the CGH and blank material (~1 mm). The intensity pattern also changes dramatically as the distance changes, making it difficult to exactly predict the expected pattern.

Further to Mr. Sutherland's previously submitted Declaration, holograms in PDLCs form Bragg gratings. This is the case with the claimed invention. These are fundamentally different from Raman-Nath gratings. In Bragg gratings, two waves continuously exchange energy to produce a single diffracted mode from the reference beam. The grating in essence filters out all of the other modes so that at the output of the hologram only the 0-order and 1-order are present [H. Kogelnik, *Bell Syst. Tech. J.* **48**, 2909-2946 (1969); L. Solymar and D. J. Cooke, *Volume Holography and Volume Gratings*, Academic Press, New York, 1981, Chs. 4 and 5; for experimental confirmation, see also H. V. Hance and J. K. Parks, *J. Ac. Soc. Am.* **38**, 14-23 (1965); J. M. Hammer et al., *Proc. IEEE* **63**, 325-326 (1975); B. J. Chang, *Proc. SPIE* **177**,

71-81 (1979); E. A. Chandross et al., *Appl. Opt.* **17**, 566-573 (1977); K. Biedermann et al., *Opt. Comm.* **6**, 205-209 (1972)]. These superpose to create an intensity modulation with no phase modulation. The diffraction of this pattern over the same distances in the near field as those in Fig. 12 of Appendix B is calculated using the diffraction integral, and the results are illustrated by the series of plots in Fig. 13 of Appendix B. The wavelength is still  $0.5\ \mu\text{m}$ , but the pitch has changed to  $\Lambda=0.5\ \mu\text{m}$  to reflect the fact that the grating is in the Bragg regime. This is apparent from the difference in scale along the  $x$  axis. The illustrated pattern shown as solid lines, stays constant and very closely replicates the desired intensity pattern shown as dashed lines. These are exactly the conditions required for contact printing.

There is no improvement in technology that will allow smaller grating pitch and hence improve the case for using CGH in LCD as described in Amako et al. for contact printing. As described herein, the limitations result from fundamental physics. Even assuming, *arguendo*, that a factor of 5 reduction in pixel size is somehow achievable for the CGH in LCD, this is still well within the Raman-Nath regime ( $\lambda/\Lambda=0.025$ ). The series of plots in Fig. 14 of Appendix B show the diffraction patterns in the near field for such a grating. The pattern is sensitive to position along the  $z$  axis for this fine grating. In fact, the amplitude modulation goes completely to zero at  $z=1.6\ \text{mm}$ . This is a result of the Talbot effect, which states that light with a pure phase modulation at the exit of a hologram returns to a pure phase modulation after it diffracts over a distance equal to one-half of the Talbot cycle [GLAD 4.5 Theoretical Discussion, Applied Optics Research, Austin, Texas, 1997,

Section 4]. In this example, the Talbot cycle is 3.2 mm. Hence, from a contact printing point of view, replication deteriorates further as pitch is reduced. Only when the grating is well within the Bragg regime does one get a faithful reproduction of the master grating (hologram).

(c) The Holograms of Amako et al. Cannot Replicate Reflection Holograms Through Contact Copying

Heretofore, it has been shown that there is no reasonable expectation that a transmission CGH in LC, like that of Amako, can be used as a master hologram in contact printing. As discussed herein, there is also no reasonable expectation that a reflection CGH in LC can be used as a master hologram in contact printing. Figure 15 of Appendix B illustrates the system for forming a reflection master hologram optically. Instead of directing the reference and object beams from the same side of the recording medium, the beams are directed from opposite sides. The resulting intensity pattern is shown. With visible light recording, the pitch in these cases is typically  $<0.2 \mu\text{m}$ . Figure 16 of Appendix B shows how a reflection hologram is replicated.

In a reflection hologram the index modulation runs in a direction along the short dimension of the medium. To create this by electrically modulating an LC (i.e., a CGH in LCD), a putative concept is shown in Fig. 17 of Appendix B. The electrodes are placed orthogonally to those in Figs. 5 and 7. This configuration radically violates the condition that electrode lateral dimensions be large compared to the separation from the ground plane. Fringe fields would totally destroy any

attempted modulation. Moreover, the voltages required for this configuration would be orders of magnitude larger than in conventional LCDs, and arcing between electrodes would result. There is no reasonable expectation that a reflection CGH in LC could be used as a master in contact printing.

Consequently, the cited art does not meet the limitations of independent claims 1, 22, 32, and 46. The Examiner has not provided any reference that teaches (1) the use of a variable diffraction efficiency master hologram in a contact printing process or (2) the use of a variable diffraction efficiency master hologram in a contact printing process wherein the printed hologram is a replica of the master hologram and exhibits the attribute of variable diffraction efficiency. Further, there is no reasonable expectation that the combination of references would successfully result in the claimed subject matter. Every pending claim proposes at least the limitation set forth in (1) above. Since none of the cited references disclose at least (1), claims 1, 2, 9-11, 22-24, 32-43 and 46 of the present application are patentable over the cited references as none of the references, either singly or in combination, teaches or suggests the claimed subject matter.

**B. The Examiner's Rejection of Claims 32-35 and 37-40 and 46 Under 35 U.S.C. 103(a) as Being Unpatentable over Sturdevant '946, in View of Redfield '861, Hall et al. '326 and Amako et al. '214 is Improper.**

For at least the reasons stated under paragraph A, the combination of limitations recited in claims 32-35, 37-40, and 46 are not met, either independently or in combination, by the cited art. Absent a reference teaching each of these limitations, the Examiner has failed to establish a *prima facie* case of unpatentability

since each limitation is not recited in the references cited by the Examiner. Further, even assuming *arguendo* that each limitation was found in the cited references, the Examiner has still failed to establish a *prima facie* case since there is no reasonable expectation that the combination of the references would result in the claimed subject matter. (See Paragraph A. and Sutherland's declaration).

**C. The Examiner's Rejection of Claims 1-31 under 35 U.S.C. §103(a) as Being Unpatentable over Sutherland et al. WO 98/04650, in View of Margerum et al. '568 Combined with Either Eguchi et al. JP 03-188479, Wreede et al. '118 or Ikeda et al. EP 0087281 and Further in View of Hall et al. '326 and Amako et al. '214 is Improper.**

For at least the reasons stated under paragraph A, the combination of limitations recited in claims 1-31 are not taught or suggested, either independently or in combination, by the cited art. Further, neither Sutherland et al., Margerum et al., Eguchi et al., Wreede et al., or Ikeda et al., teach or suggest (a) a variable diffraction efficiency master hologram used in contact printing and (b) contact printing of a master hologram having a variable diffraction efficiency resulting in a replica hologram having the variable diffraction efficiency characteristics of the master hologram, at least one of which is required in each of the independent claims.

Sutherland et al. is cited as teaching PDLC holographic recording medium which are used to record gratings, the general compositions thereof, stacking of the gratings, and the use of two beam exposure processes with the PDLC materials. Margerum et al. is cited for teaching the use of a contact exposure through a grating mask to form diffraction gratings in PDLC recording materials; the use of a second exposure after the masked exposure; and the use of two beam holographic

interference. Eguchi et al. is cited for teaching contact copying of a reflection hologram where the incident beam passes through the recording medium and is diffracted to form a beam by the underlying reflection medium. Wreede et al. is cited for teaching contact copying of reflection holograms where the incident beam passes through the recording medium and is diffracted to form a beam by the underlying reflection hologram. Ikeda is cited for teaching a master hologram which is placed in close contact with a photosensitive layer and exposed to form a copy hologram. These references do not teach or suggest (a) a variable diffraction efficiency master hologram used in contact printing and (b) contact printing of a master hologram having a variable diffraction efficiency resulting in a replica hologram having the variable diffraction efficiency characteristics of the master hologram.

Absent a reference teaching each of these limitations, the Examiner has failed to establish a *prima facie* case of unpatentability since each limitation is not recited in the references cited by the Examiner. Further, even assuming *arguendo* that each limitation was found in the cited references, the Examiner has still failed to establish a *prima facie* case since there is no reasonable expectation that the combination of the references would result in the claimed subject matter. (See Paragraph A. and Sutherland's declaration).

Additionally, the claims of Group III are directed to a system for duplicating a reflection hologram via contact copying. The cited references do not meet the limitations of the claimed system. Further, Dr. Sutherland, an inventor of the claimed subject matter, has provided theoretical evidence that no combination of the prior art

disclosures could result in the subject matter of claim 12. More particularly, paragraph 12 of Dr. Sutherland's declaration states,

Further, the CGH in LC forms only a two-dimensional pattern. This is dictated by the fact that the electrodes are arrayed on the bounding surfaces of the LC device. Hence the index modulation can only be induced in the plane of the LC device. This by definition forms a transmission grating, i.e., the diffracted beams emanate from the side opposite the impinging beam. **Therefore, a CGH in LC cannot form a reflection grating, where the index modulation is perpendicular to the bounding surfaces. The only way it could do this would be to distribute the electrodes through the volume of the LC, which is not even remotely possible with current or foreseeable active matrix technology.**

(emphasis added). Consequently, the Examiner has failed to establish a *prima facie* case either for failure to cite references that recite each and every limitation in the claims or for failure to show there is a reasonable expectation that the combination of the references would result in the claimed subject matter. (See Paragraph A and Sutherland's declaration).

**D. The Examiner's Rejection of Claim 48 Under 35 U.S.C. 103(a) as Being Unpatentable over Gambogi et al. '011, in View of Hall et al. '326, Kato et al. '504, Sutherland et al. WO 98/04650 and Ikeda et al. EP 0087281 is Improper.**

For at least the reasons stated under paragraph A with respect to Hall et al., the combination of limitations recited in claim 48 of Group IV are not met, either independently or in combination, by the cited art. (See paragraph A. and Sutherland's declaration). The Examiner has failed to establish a *prima facie* case of unpatentability since each limitation is not recited in the references cited by the Examiner. Neither Gambogi et al., Kato et al., Hall et al., Ikeda et al., or Sutherland

et al., teach or suggest (c) a stack of first, second, and third master holograms in optical contact with first, second, and third holographic blanks, (d) switching on a first master hologram of the stack of master holograms during exposure of the stack of master holograms by a recording beam, (e) switching off a first master hologram of the stack of master holograms and switching on a second master hologram of the stack of master holograms during exposure of the stack of master holograms by a recording beam, or (f) forming replicas of the any one of the first, second, or third master holograms in any one of the first, second, or third holographic blanks.

More particularly, the Examiner states with regard to Gambogi et al,

[t]he photosensitive medium shown in figure 10a shows the use of a holographic master in contact copying followed by the curing step in 10b. The different holographic recording layers in figures 11, 12, 14, 22, 23 and 25 were differently sensitized to record only a single wavelength range.

This language refers to a single master. Claim 48 describes a stack of master holograms comprising at least a first, second, and third master hologram. Further, Gambogi et al. does not describe switching on or off the single master during exposure thereof by a recording beam. Consequently, Gambogi et al. does not teach or suggest any of limitations (c)-(f) of claim 48.

Similarly, none of limitations (c)-(f) are taught or suggested by Kato et al., which the Examiner cites as teaching, “the stepping of the LCD between successive exposures to record objects at different distances.” This teaching does not teach or suggest limitations (c)-(f).

Likewise, the Examiner cites Ikeda et al. for its teaching of contact copying. The undersigned representative does not dispute that contact copying was known

prior to the conception of the claimed invention. Unfortunately, Ikeda et al., does not cure the deficiencies of Hall et al, Gambogi et al., and Kato et al. Ikeda et al. does not teach any of limitations (c)-(f), all of which must be taught in order to establish a *prima facie* case of obviousness under 35 U.S.C. §103.

Finally, the Examiner cites Sutherland et al. for “a multilayered PDLc holographic master.” The undersigned representative agrees with the Examiner that Sutherland et al. does describe a multilayered PDLc hologram. This disclosure does not teach or suggest any of limitations (c)-(f) of claim 48.

Since neither Gambogi et al., Hall et al., Kato et al., Ikeda et al., or Sutherland et al., teach or suggest any one of limitations (c)-(f) of claim 48, the Examiner has failed to establish a *prima facie* case of unpatentability. Further, even assuming *arguendo* that each limitation was found in the cited references, the Examiner has still failed to establish a *prima facie* case since there is no reasonable expectation that the combination of the references would result in the claimed subject matter.

(9) **Conclusion**

For at least the reasons given above, the rejections of claims 1-43, 46, and 48 are improper. Applicant respectfully requests the final rejection by the Examiner be reversed and claims 1-46, and 48 be allowed.

Respectfully submitted,

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**APPENDIX OF CLAIMS**

1. A system for duplicating a hologram comprising:
  - a radiation source for emitting a coherent beam of radiation;
  - a hologram having variable diffraction efficiency; and
  - a recording substrate comprised of a polymer-dispersed liquid crystal material for recording a replica of the hologram therein, wherein the hologram and the recording substrate are in optical contact with one another and are placed in a path of the coherent beam of radiation.
2. The system according to claim 1, wherein the polymer-dispersed liquid crystal material is comprised of:
  - (a) a polymerizable monomer comprising at least one acrylate;
  - (b) at least one type of liquid crystal material;
  - (c) a chain-extending monomer;
  - (d) a coinitiator; and
  - (e) a photoinitiator.
3. The system according to Claim 2, wherein the polymerizable monomer comprises a mixture of di-, tri-, tetra-, and penta-acrylates.
4. The system according to Claim 2, wherein the polymerizable monomer is at least one acrylate selected from the group consisting of triethyleneglycol diacrylate, trimethylolpropane triacrylate, pentaerythritol triacrylate, pentaerythritol tetracrylate, and dipentaerythritol penta-acrylate.

5. The system according to Claim 2, wherein the polymerizable monomer comprises a mixture of tri- and penta-acrylates.
6. The system according to Claim 2, wherein the polymerizable monomer comprises dipentaerythritol pentaacrylate.
7. The system according to Claim 1, wherein the polymer-dispersed liquid crystal material further comprises a surfactant.
8. The system according to Claim 7, wherein the surfactant is octanoic acid.
9. The system according to Claim 2, wherein the polymerizable monomer comprises dipentaerythritol pentaacrylate, the at least one liquid crystal material comprises a mixture of cyanobiphenyls, the chain-extending monomer is N-vinyl pyrrolidone, the coinitiator is N-phenylglycine, and the photoinitiator is rose bengal.
10. The system according to claim 1, wherein the radiation source is a laser.
11. The system according to claim 1, wherein a diffraction efficiency of the hologram is continuously variable.

12. A method for duplicating a hologram comprising:

directing a coherent incident radiation beam at a first optical component;

transmitting the coherent incident radiation beam through the first optical component forming a transmitted beam, to a second optical component having a hologram with variable diffraction efficiency recorded therein; and

diffracting the transmitted beam via the hologram forming a diffracted radiation beam, wherein the coherent incident radiation beam and the diffracted beam interfere within the first optical component to form a replica of the hologram therein.

13. The method for duplicating a hologram according to claim 12, wherein the first optical component is comprised of a polymer-dispersed liquid crystal material.

14. The method according to claim 13, wherein the polymer-dispersed liquid crystal material is comprised of:

- (a) a polymerizable monomer comprising at least one acrylate;
- (b) at least one type of liquid crystal material;
- (c) a chain-extending monomer;
- (d) a coinitiator; and
- (e) a photoinitiator.

15. The method according to Claim 14, wherein the polymerizable monomer comprises a mixture of di-, tri-, tetra-, and penta-acrylates.

16. The method according to Claim 14, wherein the polymerizable monomer is at least one acrylate selected from the group consisting of triethyleneglycol diacrylate, trimethylolpropane triacrylate, pentaerythritol triacrylate, pentaerythritol tetracrylate, and dipentaerythritol penta-acrylate.

17. The method according to Claim 14, wherein the polymerizable monomer comprises a mixture of tri- and pentaacrylates.

18. The method according to Claim 14, wherein the polymerizable monomer comprises dipentaerythritol pentaacrylate.

19. The method according to Claim 14, wherein the polymer-dispersed liquid crystal material further comprises a surfactant.

20. The method according to Claim 19, wherein the surfactant is octanoic acid.

21. The method according to Claim 14, wherein the polymerizable monomer comprises dipentaerythritol pentaacrylate, the at least one liquid crystal material comprises a mixture of cyanobiphenyls, the chain-extending monomer is N-vinyl pyrrolidone, the coinitiator is N-phenylglycine, and the photoinitiator is rose bengal.

22. A method for duplicating a hologram comprising:
- directing a coherent radiation beam at a first optical component having a hologram with variable diffraction efficiency recorded therein;
  - diffracting a first portion of the coherent radiation beam via the hologram forming a diffracted radiation beam;
  - transmitting a second portion of the coherent radiation beam through the first optical component forming a transmitted beam; and
  - interfering the diffracted radiation beam with the transmitted radiation beam within a second optical component to form a replica of the hologram therein.
23. The method for duplicating a hologram according to claim 22, wherein the second optical component is comprised of a polymer-dispersed liquid crystal material.
24. The method according to claim 23, wherein the polymer-dispersed liquid crystal material is comprised of:
- (a) a polymerizable monomer comprising at least one acrylate;
  - (b) at least one type of liquid crystal material;
  - (c) a chain-extending monomer;
  - (d) a coinitiator; and
  - (e) a photoinitiator.
25. The method according to Claim 24, wherein the polymerizable monomer comprises a mixture of di-, tri-, tetra-, and penta-acrylates.

26. The method according to Claim 24, wherein the polymerizable monomer is at least one acrylate selected from the group consisting of triethyleneglycol diacrylate, trimethylolpropane triacrylate, pentaerythritol triacrylate, pentaerythritol tetracrylate, and dipentaerythritol pentaacrylate.

27. The method according to Claim 24, wherein the polymerizable monomer comprises a mixture of tri- and penta-acrylates.

28. The method according to Claim 24, wherein the polymerizable monomer comprises dipentaerythritol pentaacrylate.

29. The method according to Claim 24, wherein the polymer-dispersed liquid crystal material further comprises a surfactant.

30. The method according to Claim 29, wherein the surfactant is octanoic acid.

31. The method according to Claim 24, wherein the polymerizable monomer comprises dipentaerythritol pentaacrylate, the at least one liquid crystal material comprises a mixture of cyanobiphenyls, the chain-extending monomer is N-vinyl pyrrolidone, the coinitiator is N-phenylglycine, and the photoinitiator is rose bengal.

32. A method for contact recording at least one hologram comprising:  
arranging at least a first master hologram having variable diffraction efficiency and at least a first holographic blank in optical contact to form a master/blank assembly;  
exposing the master/blank assembly to a pre-recording beam; and  
exposing the master/blank assembly to a recording beam, wherein the master/blank assembly remains optically contacted throughout each exposure.

33. The method according to claim 32, further comprising exposing the master/blank assembly to a post-recording beam.
34. The method according to claim 32, wherein a diffraction efficiency of the first master hologram is continuously variable.
35. The method according to claim 34, wherein the continuously variable diffraction efficiency of the first master hologram includes at least the following two states, ON and OFF.
36. The method according to claim 32, wherein the first master hologram is formed of a polymer-dispersed liquid crystal material.
37. The method according to claim 35, wherein the continuously variable first master hologram is switched OFF during exposure of the master/blank assembly to the pre-recording beam and the first master hologram is switched ON during exposure of the master/blank assembly to the recording beam, thereby forming a first replica of the first master hologram in the first holographic blank.
38. The method according to claim 37, wherein the first master hologram is switched OFF during exposure of the master/blank assembly to the post-recording beam.
39. The method according to claim 33, wherein the pre-recording beam, the recording beam, and the post-recording beam are the same beam.
40. The method according to claim 33, wherein of the pre-recording beam, the recording beam, and the post recording beam at least one is different from the others.
41. The method according to claim 37, wherein a diffraction efficiency of the first replica is continuously variable.

42. The method according to claim 41, wherein the continuously variable diffraction efficiency of the first replica includes at least the following two states, ON and OFF.

43. The method according to claim 37, wherein the first replica is formed of a polymer-dispersed liquid crystal material.

44. The method according to claim 42, wherein the master/blank assembly further includes a second master hologram and a second holographic blank in optical contact and the first master hologram and the first replica are switched OFF during each of the following, exposure of the second holographic blank to a pre-recording beam, recording of the second master hologram in the second holographic blank, and exposure of a resulting second replica to a post-recording beam.

45. The method according to claim 44, wherein the first master hologram and the second master hologram are the same master hologram.

46. A method for contact recording at least one hologram comprising:  
arranging at least a first master hologram having variable diffraction efficiency and at least first holographic blank in optical contact to form a master/blank assembly;  
exposing the master/blank assembly to a recording beam; and  
exposing the master/blank assembly to a post-recording beam, wherein the master/blank assembly remains optically contacted throughout each exposure.

47. A system for contact recording multiple holograms comprising:
- a first, second, and third master hologram;
  - a first, second, and third holographic blank wherein the first, second, and third master hologram and the first, second, and third holographic blanks are in optical contact, forming a stack; and
  - a first, second, and third recording beam, wherein when the first recording beam is incident upon the stack, the first master hologram is ON and the second and third master holograms are OFF, forming a first replica hologram of the first master hologram in the first holographic blank; when the second recording beam is incident on the stack, the first and third master holograms are OFF, the first replica hologram is OFF, and the second master hologram is ON, forming a second replica hologram of the second master hologram in the second holographic blank; when the third recording beam is incident on the stack, the first and second master holograms are OFF, the first and second replica holograms are OFF, and the third master hologram is ON, forming a third replica hologram of the third master hologram in the third holographic blank.

48. A method for contact printing multiple master holograms comprising:

providing a stack comprised of first, second, and third master holograms and first, second, and third holographic blanks that are in optical contact;

switching ON the first master hologram;

exposing the stack with a first recording beam, forming a first replica hologram within the first holographic blank;

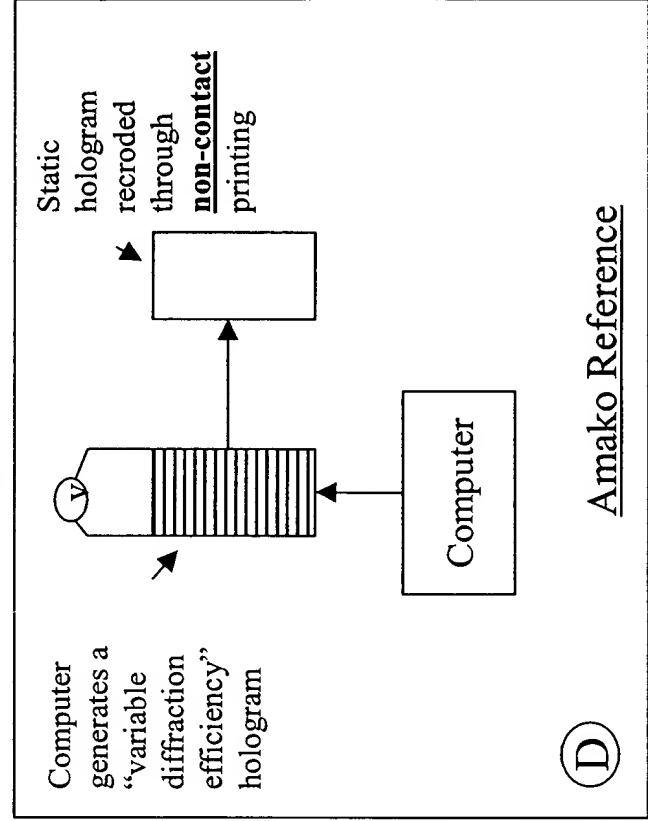
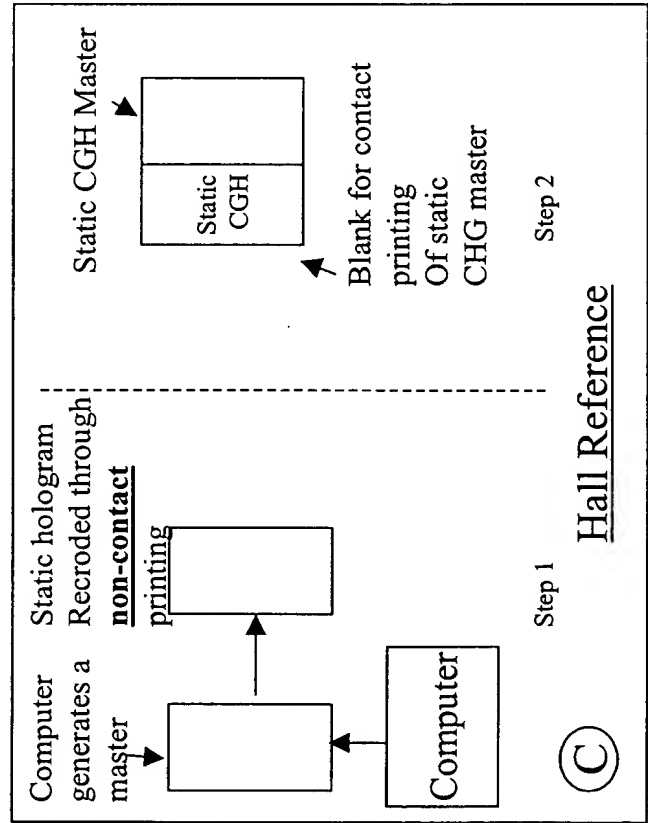
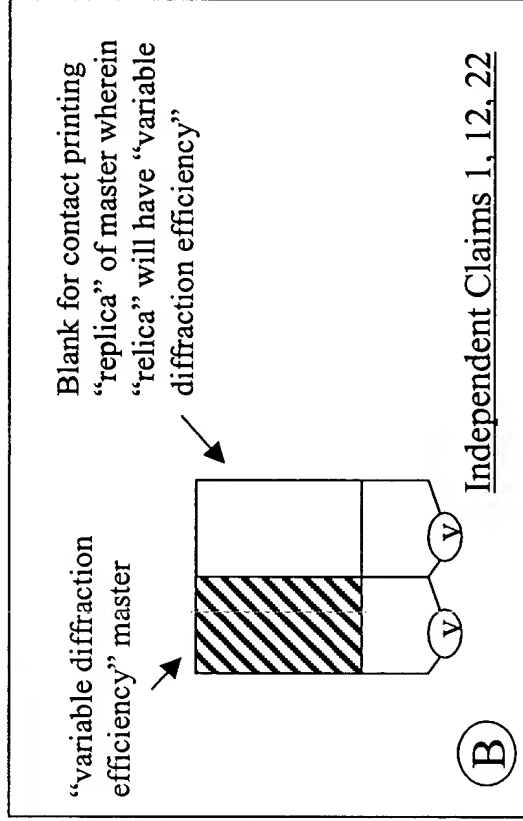
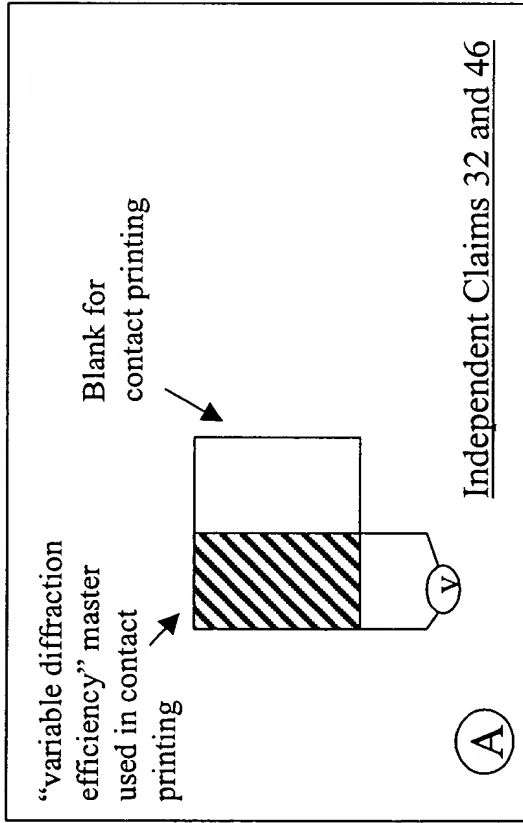
switching OFF the first master hologram and switching ON the second master hologram;

exposing the stack with a second recording beam, forming a second replica hologram within the second holographic blank;

switching OFF the second master hologram and switching ON the third master hologram; and

exposing the stack with a third recording beam, forming a third replica hologram within the third holographic blank.

# APPENDIX A



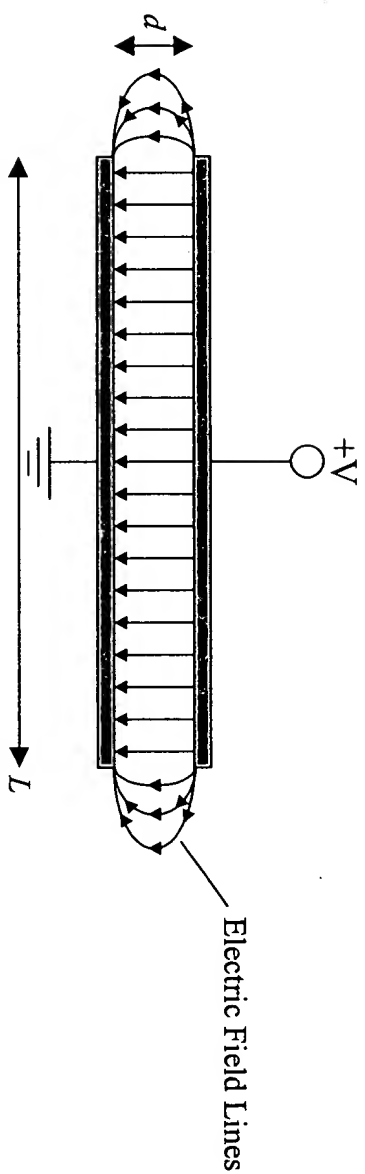


Fig. 1. Capacitor schematic showing electric field lines. Area of plates =  $L \times W$  with  $L \gg d$ ,  $W \gg d$ , and  $d$  = plate separation.

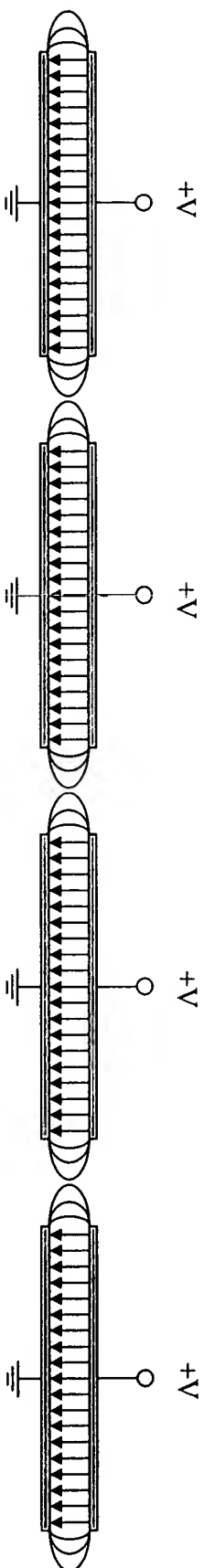


Fig. 2. Capacitor array separated by distance  $\sim 2d$  to avoid cross talk from fringing fields.

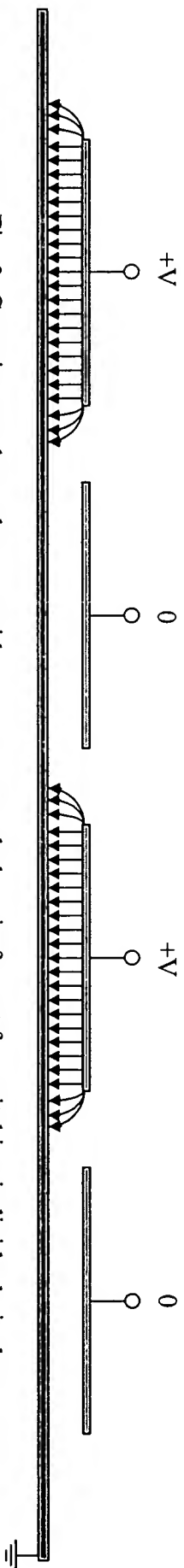


Fig. 3. Capacitor or electrode array with common ground plane in format for switching individual pixels.

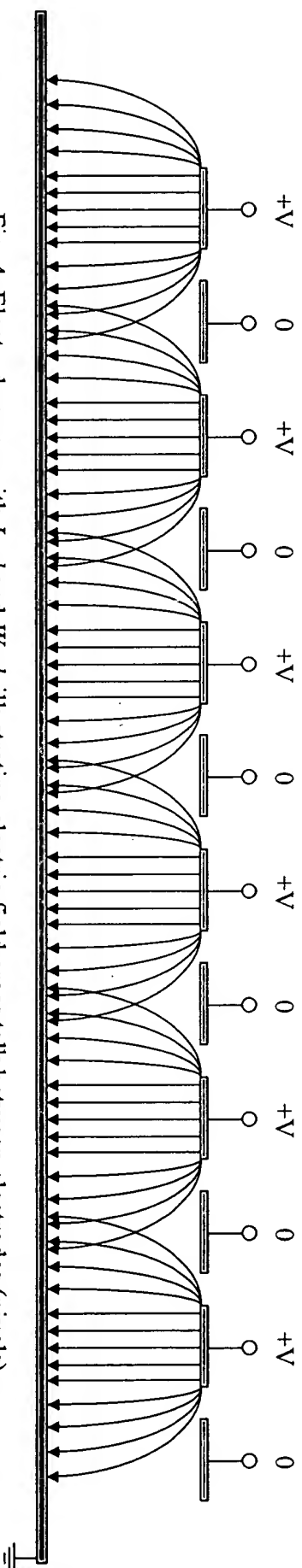


Fig. 4. Electrode array with  $L \sim d$  and  $W \sim d$ , illustrating electric field cross talk between electrodes (pixels).

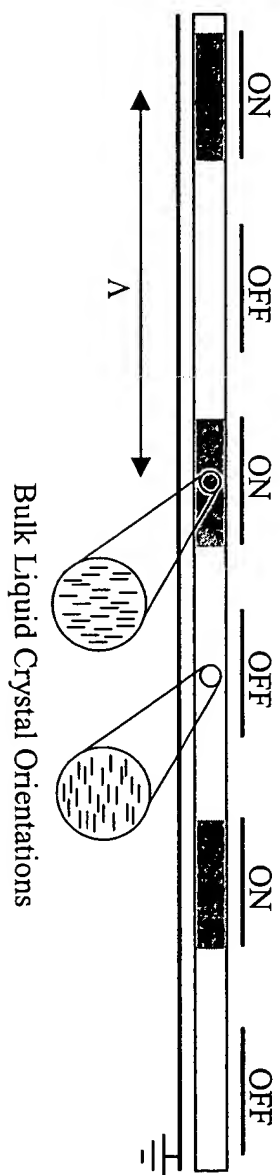


Fig. 5. Computer generated hologram (CGH) in liquid crystal device (LCD).

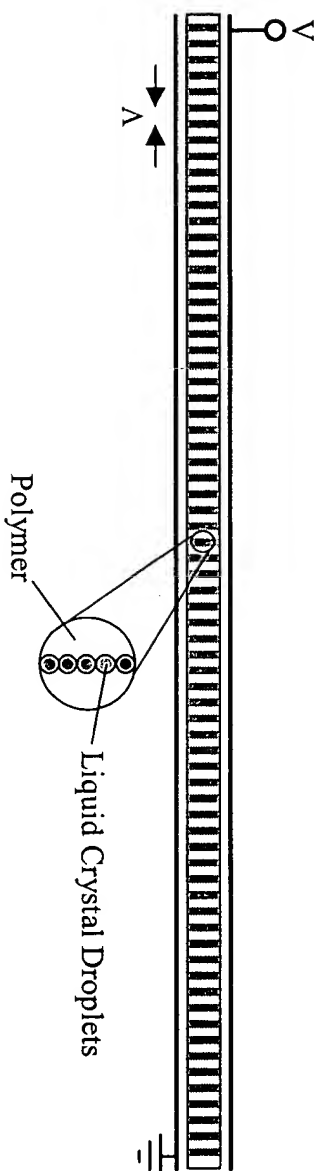


Fig. 6. Electrically switchable hologram in polymer-dispersed liquid crystal (PDLC).

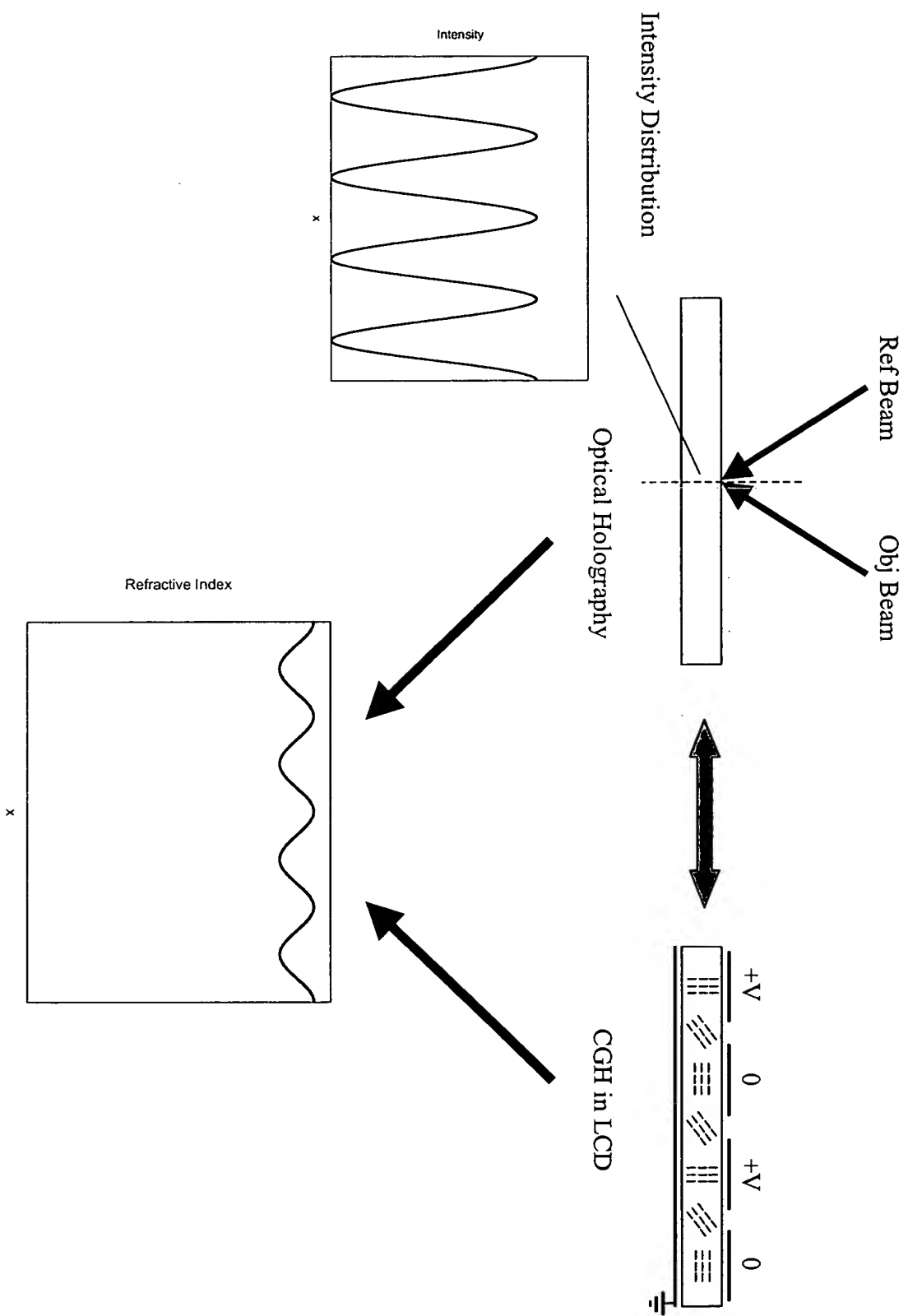


Fig. 7. Creation of a master hologram by optical holography and computer generated holography in an LC device.

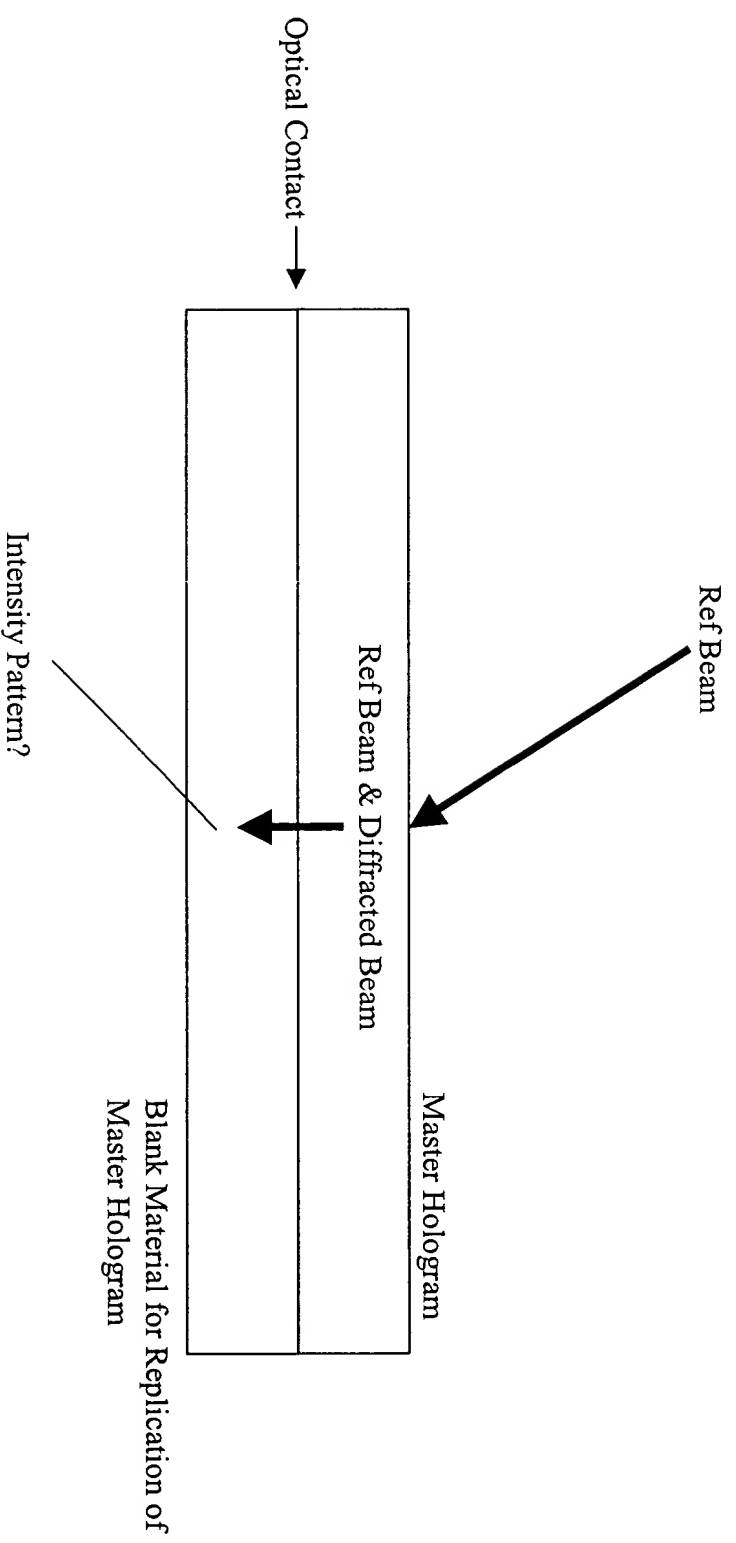


Fig. 8. Schematic diagram of hologram replication by contact printing.

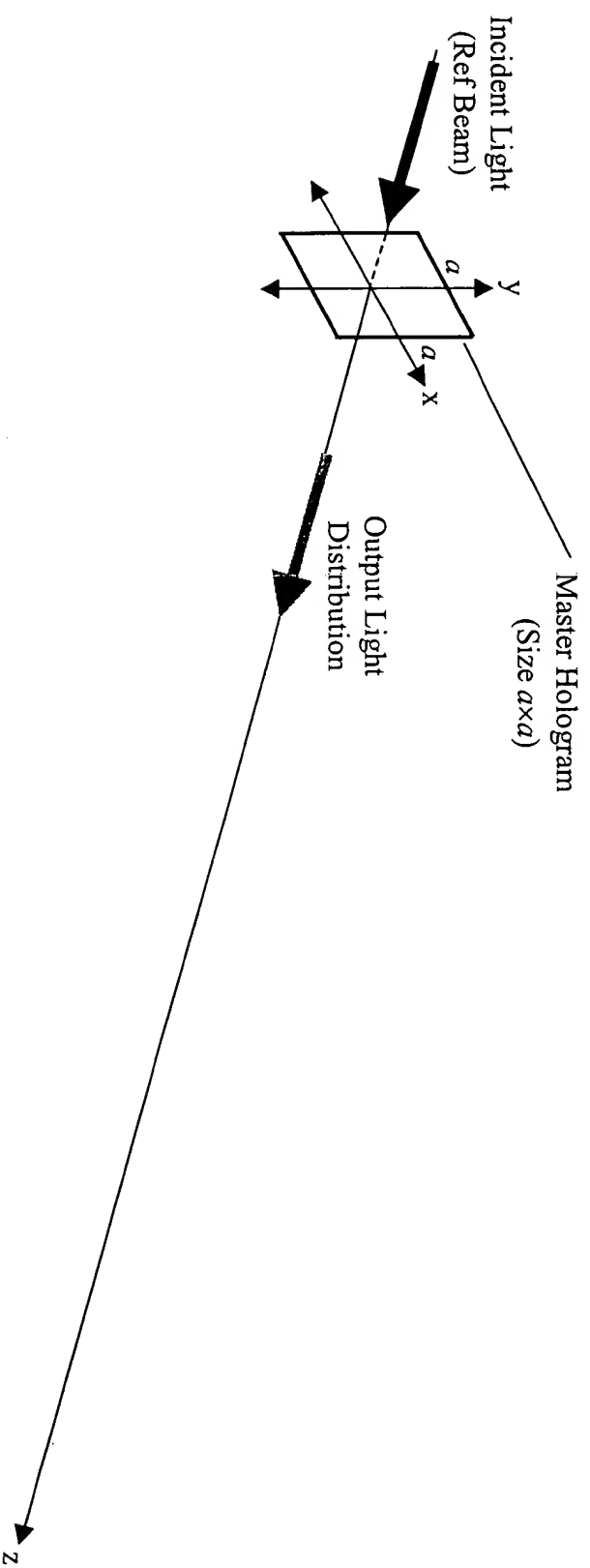


Fig. 9. Geometry for computing output light distribution (diffraction pattern) from the master hologram.

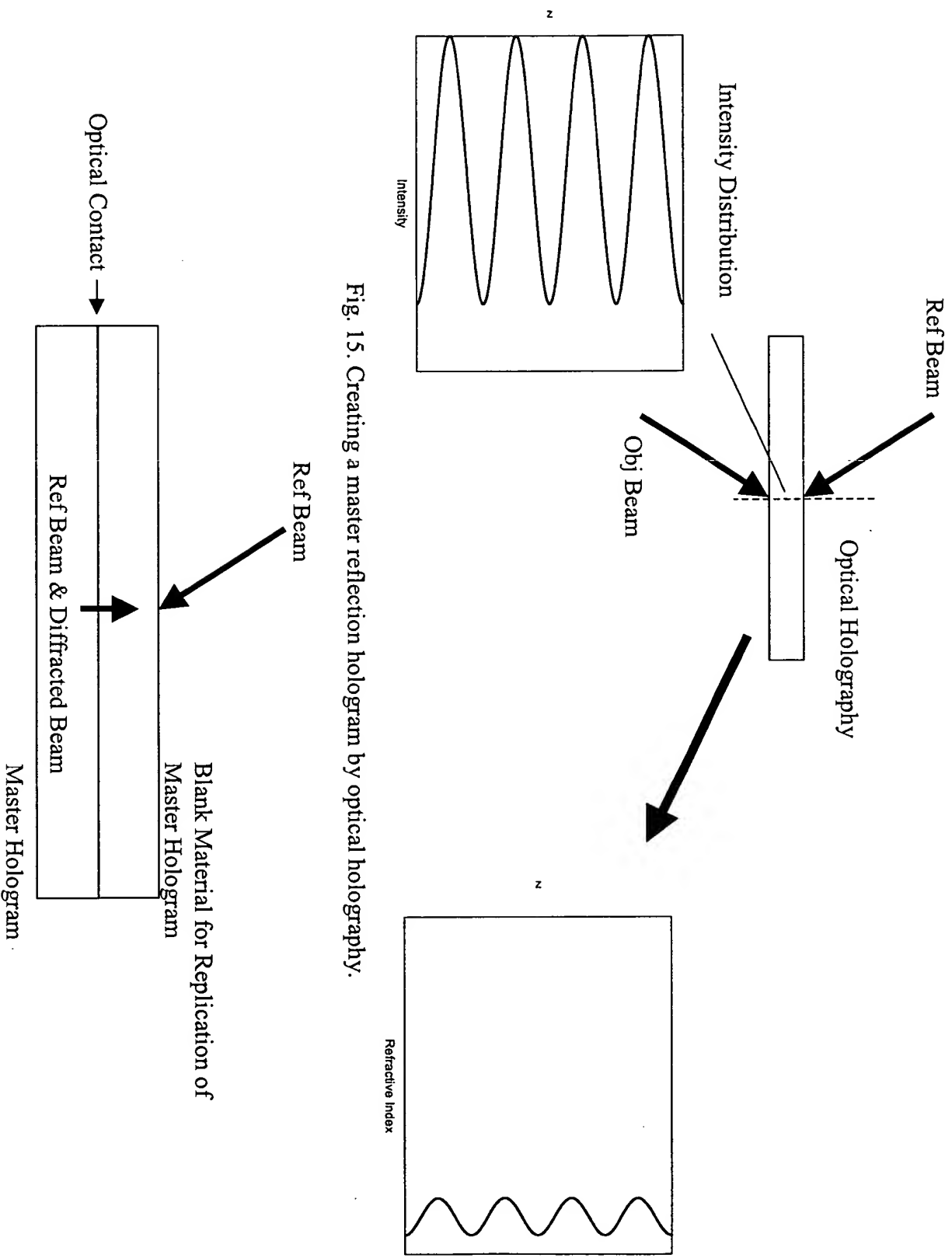


Fig. 15. Creating a master reflection hologram by optical holography.

Fig. 16. Contact printing with a reflection master hologram.

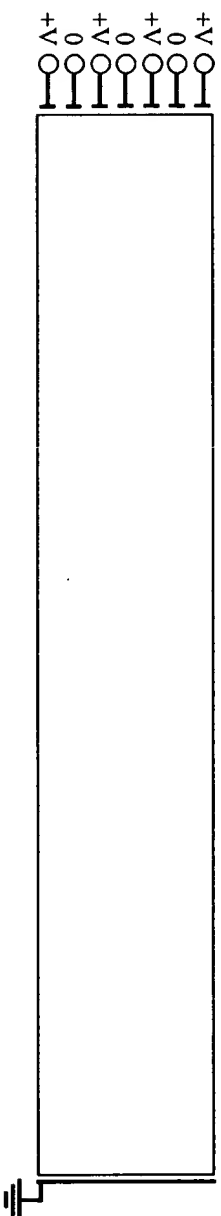


Fig. 17. Putative concept for creating a reflection hologram by CGH in LCD.

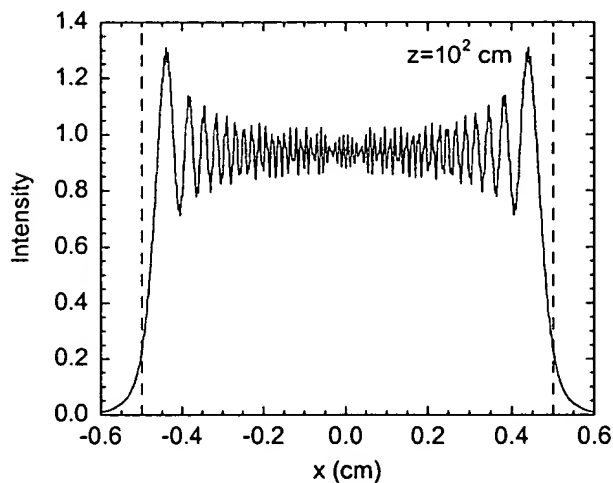
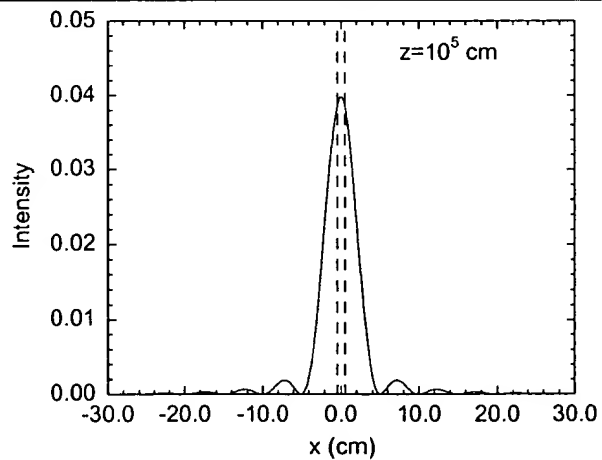
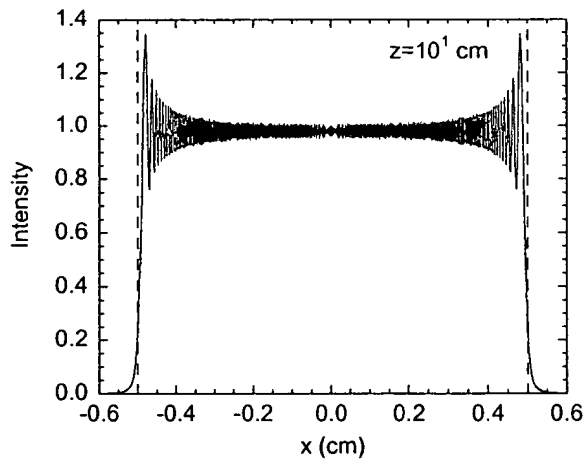
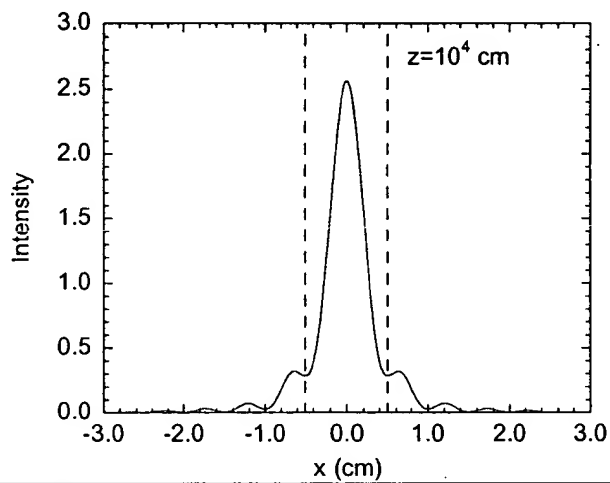
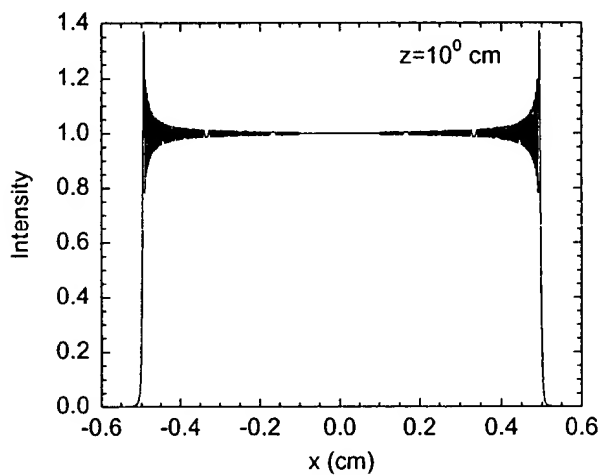
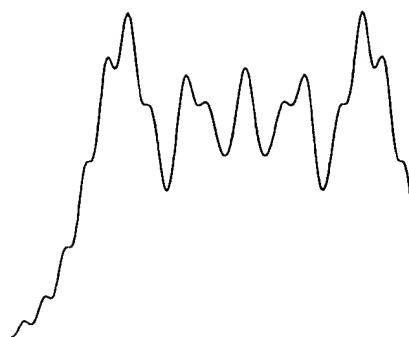
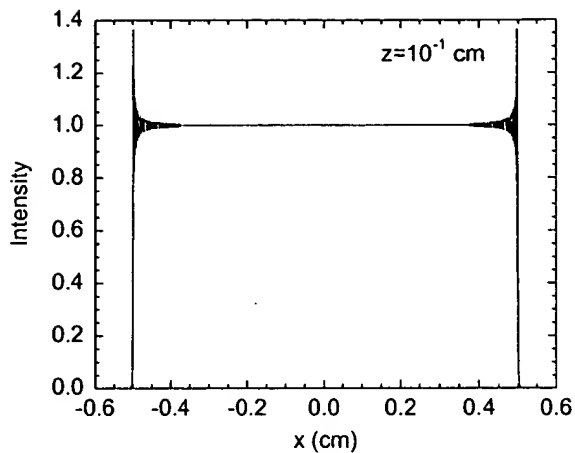


Fig. 10. Intensity patterns along  $x$  axis as function of distance  $z$  from the hologram aperture (0 modulation, e.g., empty aperture). Vertical dashed lines show aperture hard boundaries.

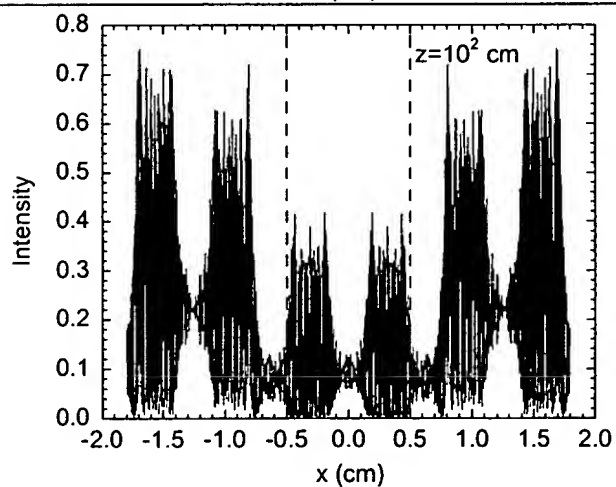
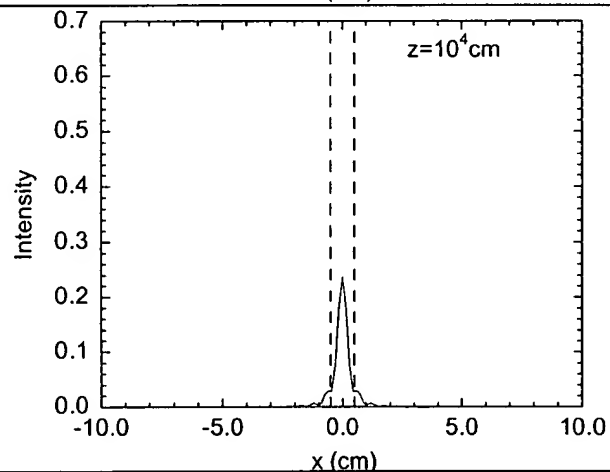
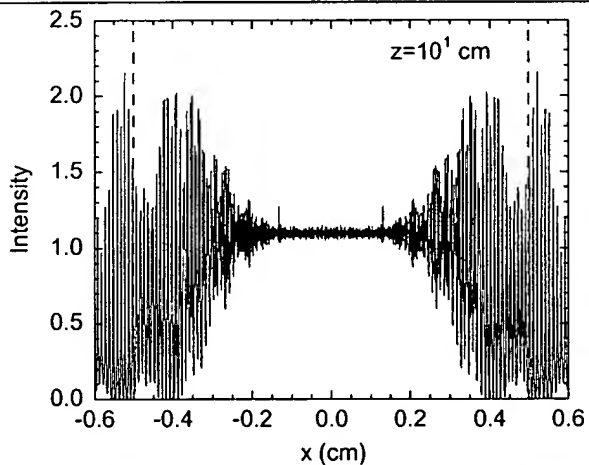
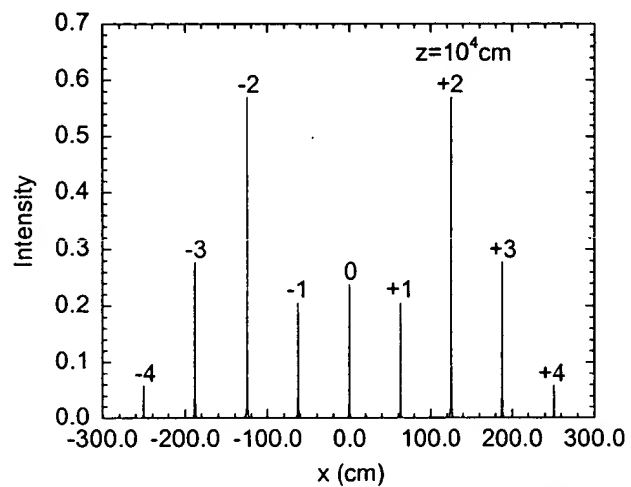
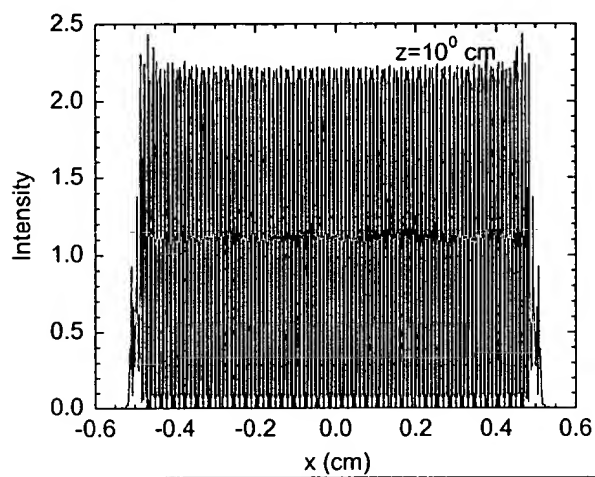
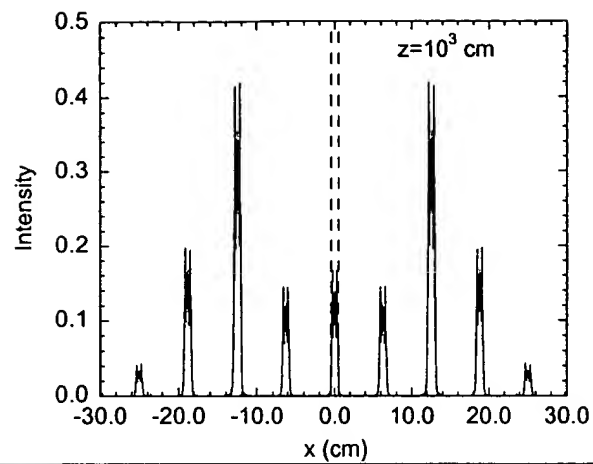
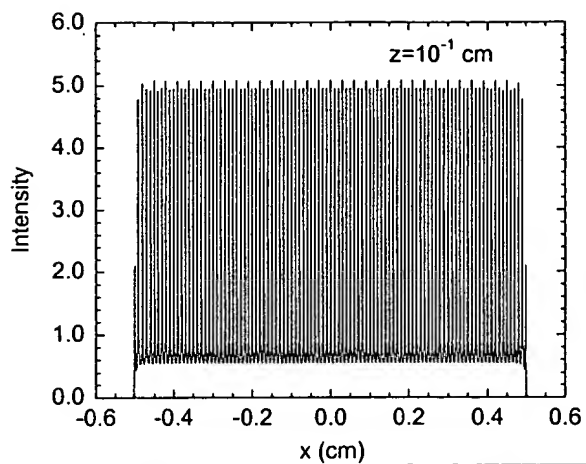


Fig. 11. Intensity patterns along  $x$  axis as functions of distance  $z$  from the hologram aperture ( $\pi$  modulation, CGH in LCD,  $\Lambda=100 \mu\text{m}$ ). Vertical dashed lines show aperture hard boundaries.

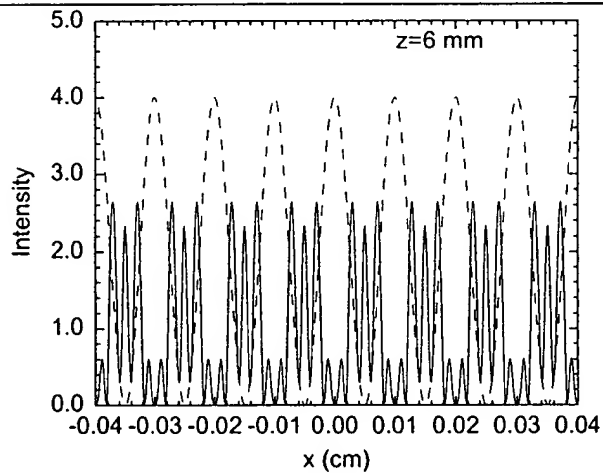
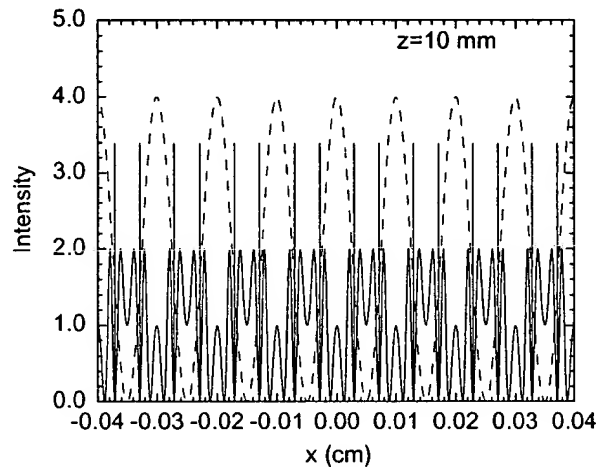
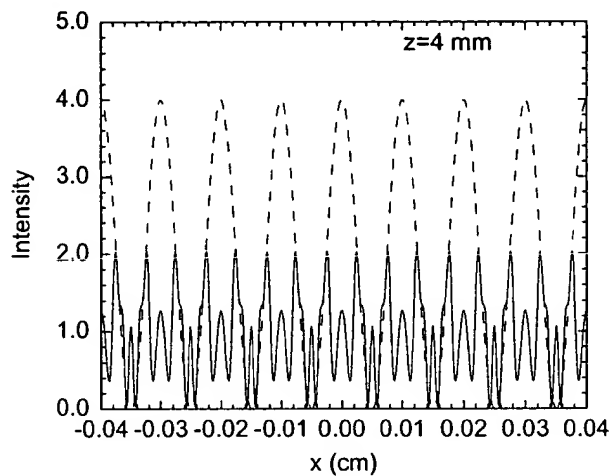
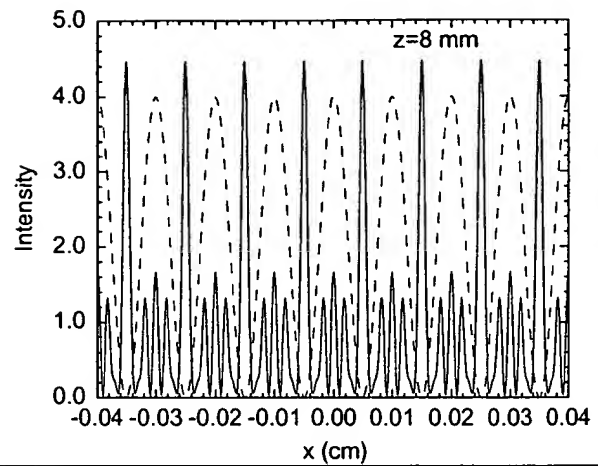
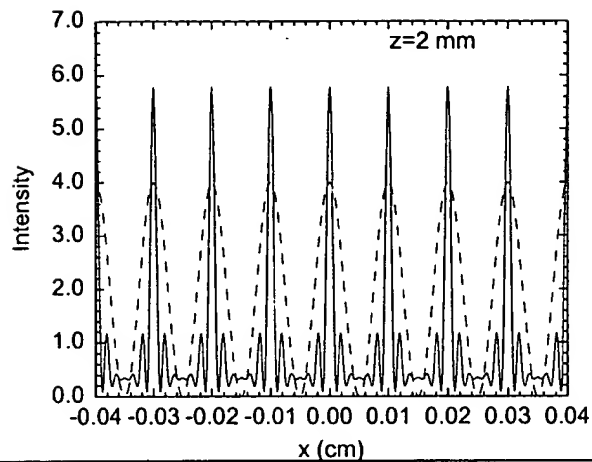


Fig. 12. Intensity patterns along  $x$  axis (zoomed in to show detail) as functions of distance  $z$  from the hologram aperture ( $\pi$  modulation, CGH in LCD,  $\Lambda=100$   $\mu\text{m}$ ). Dashed lines show intensity pattern system is attempting to replicate.

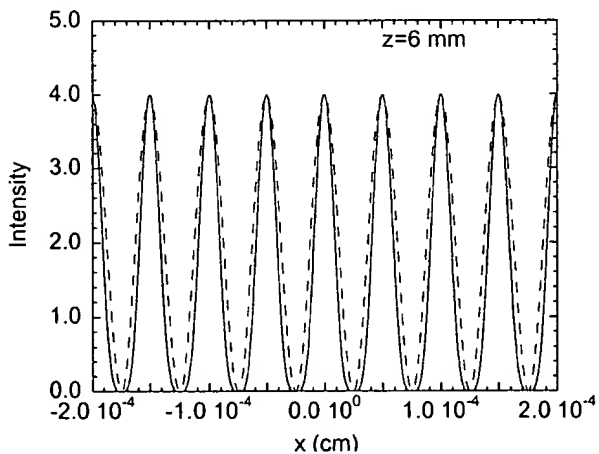
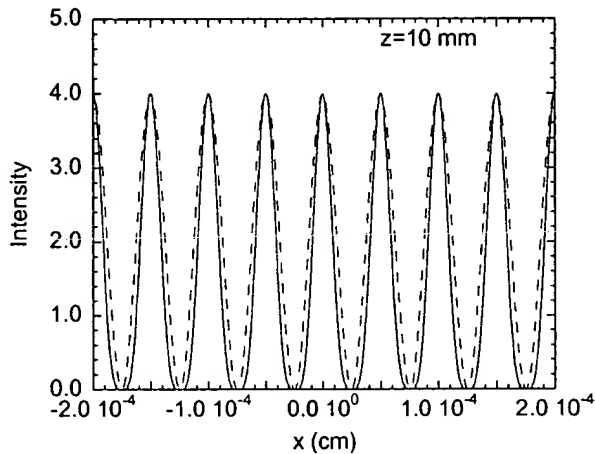
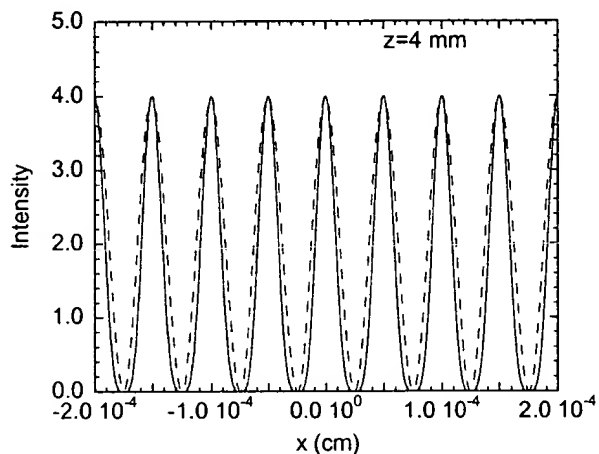
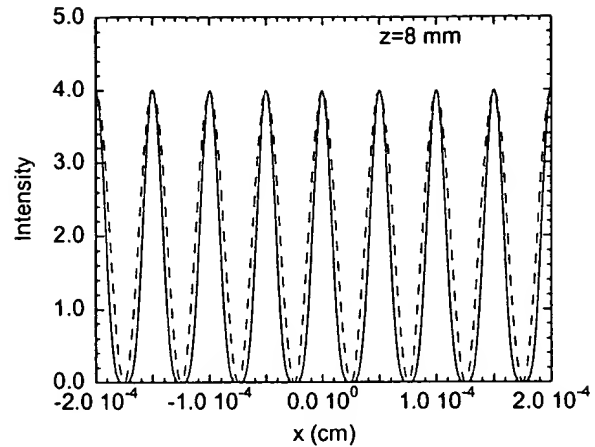
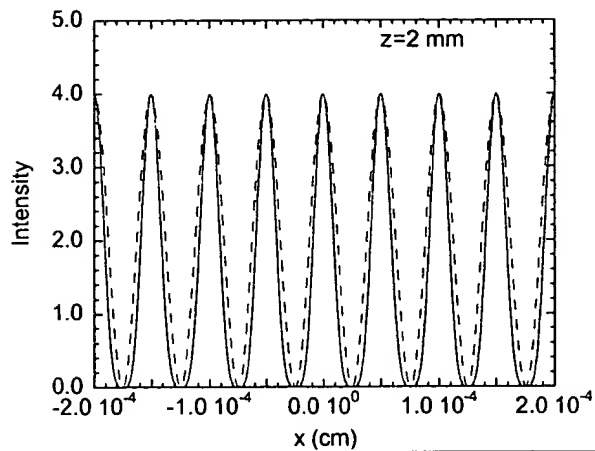


Fig. 13. Intensity patterns along  $x$  axis (zoomed in to show detail) as functions of distance  $z$  from the hologram aperture (PDLC switchable hologram,  $\Lambda=0.5 \mu\text{m}$ ). Dashed lines show intensity pattern system is attempting to replicate.

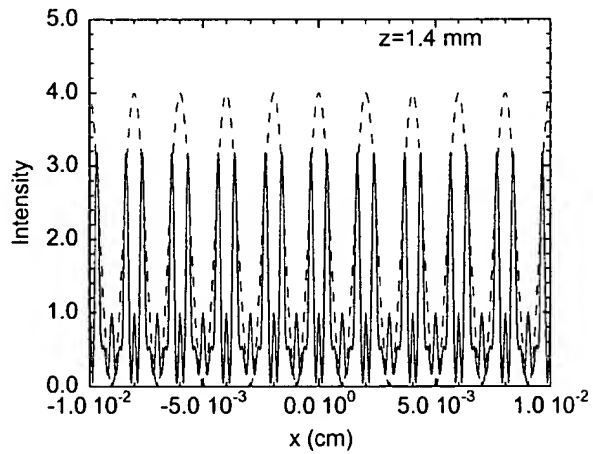
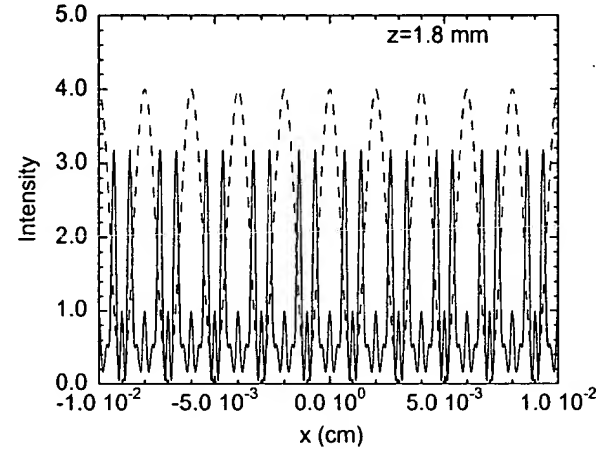
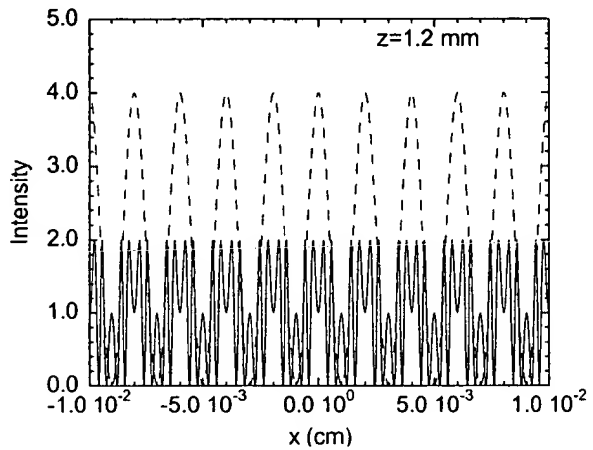
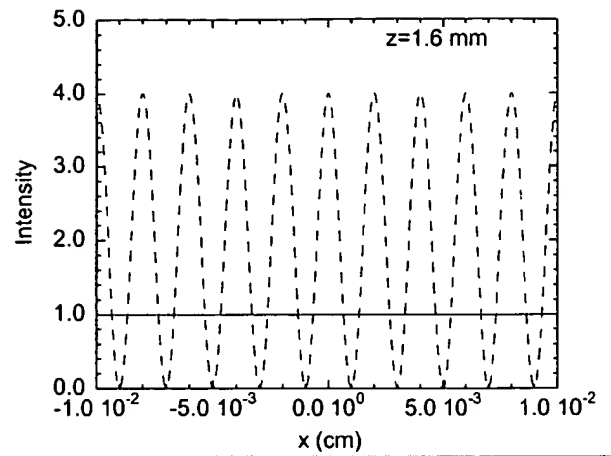
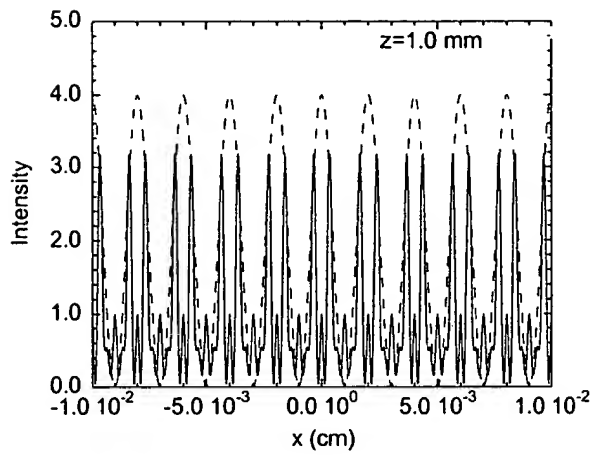


Fig. 14. Intensity patterns along  $x$  axis (zoomed in to show detail) as functions of distance  $z$  from the hologram aperture (fine-grating CHG in LCD,  $\Lambda=20$   $\mu\text{m}$ ). Dashed lines show intensity pattern system is attempting to replicate.